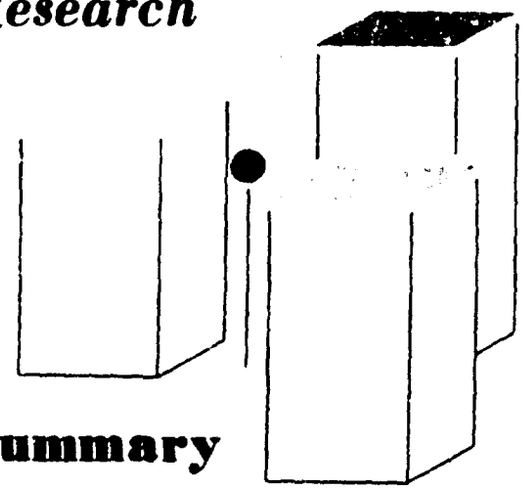
FINAL REPORT

Radiological Recovery Requirements, Structures, and Operations Research



Introduction and Summary

by

J. T. Ryan

Project Leader

PREPARED FOR THE
OFFICE OF CIVIL DEFENSE
DEPARTMENT OF THE ARMY
WASHINGTON, D. C. 20310
OCD WORK UNIT NO. 3233B

UNDER

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U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
SAN FRANCISCO, CALIFORNIA 94135
CONTRACT N228 (62479)-68153
RTI PROJECT OU-214

6 June 1966

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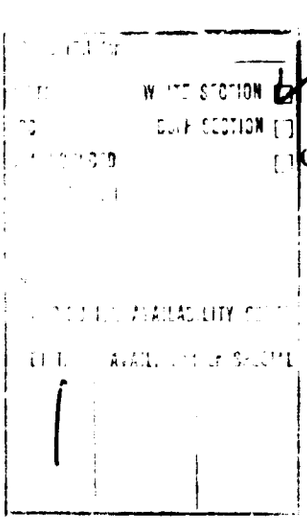

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Operations Research and Economics Division

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Radiological Recovery Requirements, Structures, and Operations Research

Prepared for the
Office of Civil Defense
Department of the Army
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under

Technical Management Office
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6 June 1966

PREFACE

The conclusions given in this report are based upon the "Engineering Manual (PM100-1)" method for calculation of "protection factors". Since an error analysis is not presently available, the conclusions should be regarded as tentative, pending the development of such an analysis. In addition, a redistribution of fallout and/or changes in the γ-ray spectrum emitted by the fallout may introduce further uncertainties into these conclusions.

FOREWORD

This is the Summary Volume for four separately bound volumes reporting research under Office of Civil Defense Subtask Number 3233B, "Radiological Recovery Requirements, Structures and Operations Research." Volume I, General Considerations, by Joseph Ryan, Thomas Johnson and Sylvia Walker, reports on the general aspects of the investigations and presents the conclusions and recommendations. Volume II, Development of Analytical, Computer and Systems Models in Support of Decontamination Analyses, by Joseph Ryan and Thomas Johnson reports on a number of models developed during the course of the contract which can be used to determine the cost and effectiveness of decontaminating municipal areas as well as to study the systems components of a command and control system for municipal decontamination. Volume III, Decontamination Analysis of Selected Sites and Facilities in San Jose, California, by Sylvia Walker, reports the computed cost and effectiveness of selected strategies of decontamination in San Jose. Volume IV, Decontamination Analysis of Selected Sites and Facilities in Detroit, Michigan, by Joseph Ryan, reports the computed cost and effectiveness of selected strategies of decontamination in Detroit. Volumes II, III, and IV serve to support the general conclusions and recommendations stated in Volume I.

The research of the authors was very ably supported by Clarence Dillard, Marvin Moss, William Davis, Arlin Benjamin, Ahmed Qadeer, Philip Rasberry, Philip McGill, Kenneth Willis and Russell Lyday.

ABSTRACT

This document summarizes the research accomplished under OCD Subtask 3233B, "Radiological Recovery Requirements, Structures, and Operations Research." The primary objective of this study is to determine cost and effectiveness information relating to the application of decontamination and the extent of its utility when applied to the recovery of extensive city areas in a postattack environment. The general approach toward meeting the objectives of the study, including a brief description of each of the models developed under the contract, is outlined. The command and control aspects of municipal decontamination are summarized, and the results of a systems analysis of decontamination are briefly stated. The results of the extensive real-cities analyses conducted under the subtask are summarized. Both general and specific conclusions and recommendations are stated.

The results of the real-cities analyses showed that roof decontamination is an important part of most combined strategies of decontamination.[1/] These results also showed that the recovery of substantial city areas and multibuilding complexes could be accelerated appreciably by practicable decontamination procedures.

[1/] These conclusions are based on somewhat idealized conditions. For example, fallout is assumed to be carried far enough away from the detector so as not to contribute at all to the radiation intensity. Other idealizations, particularly those related to weathering of fallout which may cause protection estimates to be in error, were largely ignored. Also, it should be noted that these conclusions were drawn in the light of uncertainties with regard to the accuracy of the engineering manual technique. It is recommended that research be undertaken to determine the extent to which errors are introduced and, if necessary, examine alternative problems, such as Monte Carlo techniques to possibly reduce these errors.

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Introduction and Summary

to

Radiological Recovery Requirements, Structures, and Operations Research

I. INTRODUCTION

A. Postattack Decontamination Research Program

One of the goals of the postattack decontamination research program of which this subtask is a part, is to provide planners at all levels with the necessary analyses on which to base realistic planning documents, to implement effective training programs, to procure and preposition essential decontamination equipment and material, and to design a system for coordination and control of decontamination measures. This includes providing information for planning guides and manuals for use by operating personnel in the postattack period.

B. Background and Objectives of the Study

The research reported herein was undertaken to partially meet the above broad objectives. This study is the second year's effort on OCD Subtask 3233B. The first year's effort was completed under OCD Contract OCD-PS-64-56, Radiological Recovery Concepts, Requirements, and Structures by Joseph Ryan, Joseph Douglass, Jr., and Herbert Campbell.[1/,2/] The basic conclusion of that study was that decontamination operations in a fallout environment are as

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1/ J. T. Ryan, J. D. Douglass, Jr., and H. E. Campbell. Radiological Recovery Concepts, Requirements, and Structures. Final Report: Volume I, General Considerations. Office of Civil Defense Subtask 3233B. Durham, North Carolina. Research Triangle Institute, 16 October 1964.

2/ J. T. Ryan, J. D. Douglass, Jr., and H. E. Campbell. Radiological Recovery Concepts, Requirements, and Structures. Final Report: Volume II, Specified Considerations and Supporting Documents. Office of Civil Defense Subtask 3233B. Durham, North Carolina: Research Triangle Institute, 16 October 1964.

vital to postattack recovery as shelters are to postattack survival. That study also recommended that decontamination analysis be extended to considering a coordinated recovery of metropolitan areas. This recommendation led to the second year's effort which is summarized in this report.

The objectives of the research undertaken in this study are described formally in NRDL Contract N-228 (62479)-68153, as follows:

> "Background. Under OCD Subtask 3233B, Contract No. OCD-PS-64-56, decontamination operations were analyzed to determine their potential contribution to accelerating recovery in an early postattack environment and to develop appropriate planning guides for effecting decontamination. This study concentrated on developing the appropriate theoretical basis and on testing it by analyzing the possible decontamination of several NFSS structures and the contiguous ground surfaces. From these studies, it was concluded that decontamination could effectively speed the postattack recovery but recommended that additional research be accomplished to determine the realistic costs (crew dose, training, equipment, etc.) involved when specialized structures or multi-building complexes were involved. To determine realistic cost and effectiveness information relating to the application of decontamination and the extent of its utility when applied to the recovery of extensive city areas in a realistic postattack environment, this follow-on study is initiated.
>
> "Approach. Using the operational planning guides for decontamination developed under OCD Project 3233B and related materials, decontamination of extensive city areas will be studied. City areas of various sizes, ranging from large to very small will be examined in regard to decontaminating vital sections and connecting links. Such areas will be selected from business (downtown), industrial, and suburban locations within real cities.
>
> "Certain specific facilities also will be studied to examine vital operations which may be outside a city, e.g., a manufacturing plant. Both high and low building densities are included in the above studies.
>
> "The effect of decontamination also will be determined for a number of critical facilities such as power plants, water pumping stations, etc. An attempt will be made to determine whether it is feasible to create marshalling areas or "islands" through decontamination. In determining this, a shopping center will be studied as well as a number of large indoor areas (theaters, gymnasiums, halls, etc.).
>
> "Scope of Work. For a broad spectrum of fallout conditions likely to be encountered in an early postattack nuclear environment, the contract shall analyze a number of localities specified using available planning guides to determine:

(1) The extent to which decontamination can aid the recovery of cities under various fallout environments.

(2) The cost and effectiveness of decontamination in recovering city areas.

(3) The preattack and postattack data required for decontaminating city areas with various levels of effort and/or capability.

(4) The nature and scope of command and control system elements required for conducting effective decontamination in practical situations.

(5) Those areas where existing experimental and/or theoretical data are insufficient for planning operations or assessing capabilities."

These contract specifications were modified by an Extension in Funds and Scope. The additional scope of work is as follows:

"Modification of Contract. For the purpose of the OCD Five-City Study, determine the value and costs of decontaminating specific real-city areas selected from the Study for a variety of precise attacks as prescribed, and together with work from on-going work under this contract,

(1) evaluate alternative decontamination strategies for specific situations taking into account all of the aspects of the precisely specified postattack environments including the residual effects of blast, fire, etc.;

(2) test developed decontamination hypotheses in an appropriate series of specific cases; and

(3) determine the costs in manpower, equipment, and supplies required to achieve specific levels of recovery under the prescribed attacks."

II. SUMMARY OF RESEARCH

A. Approach

As stated in Section I, decontamination operations were analyzed last year to determine their potential contribution to accelerating recovery in an early postattack environment. That study concentrated on developing the appropriate theoretical basis and on testing it by analyzing alternative decontamination procedures applied to several NFSS structures.

Extending last year's research, decontamination of urban sites and facilities of various sizes is examined. These sites and facilities, including several multi-building complexes, are selected from business (downtown), industrial, and suburban areas located in two of the cities in the Five-City Study (San Jose, California and Detroit, Michigan). Vital elements and connecting links are included. These include such critical facilities as power plants, water pumping stations, sewage treatment plants, and hospitals, as well as typical neighborhood buildings such as school buildings and gasoline stations. Further, the feasibility of creating marshalling areas or "islands" through decontamination is determined. In determining this, a shopping center is studied as well as a number of large indoor areas (e.g., a school gymnasium, a legislative amphitheater, etc.). These analyses are summarized in Section II-E below.

When this work began, it seemed that extensive multi-building complexes could not be analyzed quickly and efficiently without modifying the analysis techniques previously developed for single-facility shielding analysis. To meet what appeared to be a prerequisite to efficient decontamination analysis, a number of models were developed for approximating gamma ray intensity at a detector location in the presence of complex contaminated plane configurations. These are discussed briefly in Section II-B below. This work, although used only to develop the approach and make sample computations during the course of this contract, has significant potential uses. These uses are also discussed below in Section II-B.

Paralleling the development of the analytical models, two computer programs written in FORTRAN for the CDC-3600 computer were completed and debugged to perform most of the computations required to analyze decontamination operations as applied to several sites and facilities selected from San Jose and Detroit. These programs are described briefly in Section II-C below. A complete description of the models and the above-mentioned computer programs is included in Volume II,

Development of Analytical, Computer, and Systems Models in Support of Decontamination Analysis.

Further, the nature and scope of the command and control system elements required to effect practical decontamination are determined. The influence of direct weapons effects on the decontamination system are examined. This work is described in Section II-D below.

B. Model Development

Four models for approximating gamma ray intensity at a detector location were developed during the course of the contract. These models are described briefly below and in detail in Volume II of this report.

1. The Analog Model

A feasibility study was conducted on the applicability of the analog computer for analyzing decontamination effectiveness. The results of this study show that the decontamination process is amenable to an analog computer analysis since:

(1) The decontamination process can be described by differential equations (e.g., decontamination efficiency, ERD, etc.),

(2) Functions involved in the analyses can be generated by analog components (e.g., the $t^{-1.2}$ decay law, etc.).

Further, the output desired consists of a graphical time history of dose and dose rate associated with individuals and/or detector locations.

Analog models, typically smaller in scope than digital models, faster running, and more easily changed, were a natural choice for decontamination analysis. Investigation of the utility of analog computers led to the development of an exploratory model--an approximate simulation of a single detector location and one plane of contamination. A small 10 amplifier Donner Computer was used.

The following variables were included in the simulation:

(1) the size of the contaminated plane and its distance from the detector,

(2) all intervening shielding,

(3) the time when decontamination is begun and the amount of time to decontaminate,

(4) the decontamination efficiency in terms of the percent fallout material removed,

(5) the time interval over which dose is computed, and

(6) the decay constant.

Test runs have demonstrated the model. Additional equipment would be required for practical usefulness. The continuation of this work should be directed towards an analog model of larger size. A TR-48 Pace Electronic Analog Computer would allow the simultaneous simulation of as many as 10 contaminated planes affecting six detector locations. Such a model would provide a valuable device for training persons responsible for planning and conducting decontamination.

2. The Circular Model

A model was developed which yields a simple procedure for approximating the gamma ray intensity at a specified detector location in a complex of finite contaminated plans as are found in an urban area. This model is referred to as the Circular Model.

The Circular Model includes the effects of gamma ray attenuation, build-up, backscatter, and skyshine by employing the results of NBS Monograph 42.[1/] The model furnishes radiation contributions from various planes of contamination, at different heights, with or without barrier shielding. The

1/ L. V. Spencer. Structure Shielding Against Fallout Radiation from Nuclear Weapons. NBS Monograph 42. Washington, D. C.: National Bureau of Standards, 1 June 1962.

planes of contamination are divided into azimuthal sectors with the detector located in each instance at the origin of a polar coordinate system.

Two characteristics of decontamination analysis make the circular model inapplicable for practical usage:

(1) Several off-center locations for a given facility must often be examined.

(2) Circular symmetry is a poor approximation for multi-structure urban complexes having a rectangular pattern.

3. The Square-Grid Model

The square-grid model furnishes contributions to gamma ray intensity from square areas specified by the rectangular coordinates of their corners. Again, the effects of gamma ray attenuation, build-up, backscatter, and skyshine are included by employing the results of Spencer's NBS Monograph.

It is shown that the square-grid model can be applied to a number of arbitrarily selected detector locations with the use of overlay maps. These rectangular grid overlays are used to collect the contaminated-plane data from an urban area map. The contributions associated with each square grid are readily obtained from the model. This model has been tested and is accurate for many practical situations.

4. The Point-Source Model or the Equivalent Planes Method

The point-source model is similar to the square-grid model in that the area comprised of the contaminated planes is modeled by a rectangular grid system. Each contaminated plane is treated as a weighted point source of contamination. Error is controlled by refining the grid to keep the eccentricity (ratio of length to width), size (relative to the distance from the detector), and orientation of each of the rectangular areas (representing planes) within prescribed bounds.

A hand computation procedure based on this model was developed and partially tested. This procedure is called the Equivalent Planes Method. Although the error bounds are based on the Engineering Manual procedure for protection factor computation, a rigorous error analysis of the Equivalent Planes Method has not yet been performed. For this reason the procedure was not used in the real-cities analyses performed under this contract. The procedure, however, is straightforward in application and is amenable to quick, on-site computations.

C. Computer Programs

Two computer programs written in FORTRAN for the CDC-3600 computer were used to perform most of the computations necessary to analyze municipal decontamination. The first of these, for computing protection factors, is based on the Engineering Manual; it was written and debugged under a separate contract by RTI for the Office of Civil Defense. This program computes the separate contributions to the intensity at specified detector locations from each of the contributing planes of contamination. A complete description of this program is given in Final Report OU-205, Protection Analysis and Construction Evaluation System, by F. A. Bryan, E. L. Hill, B. W. Howard, T. Johnson, R. O. Lyday, P. S. McMullan and M. D. Wright.[1/]

The second program was written and debugged under this contract. It computes both the reductions in dose-rate at specified detector locations and the reductions in total dose for persons spending prescribed amounts of times at specified detector locations where the level of decontamination is prescribed. This program also computes the fraction of the intensity received at a detector location from each of the contributing planes of contamination. This program is described in detail in Volume II of this report.

1/ F. A. Bryan, E. L. Hill, B. W. Howard, T. Johnson, R. O. Lyday, P. S. McMullan and M. D. Wright. Protection Analysis and Construction Evaluation System. Final Report OU-205. Durham, North Carolina: Research Triangle Institute, Operations Research and Economics Division, 15 January 1965.

D. Command and Control Considerations

The nature and scope of command and control system elements required to effect practical municipal decontamination are determined. Emphasis is placed on decontamination within municipalities. The five questions (basic to decontamination analysis) upon which this aspect of the research focuses are:

(1) What are the preattack and postattack data required to effect decontamination operations?

(2) What are the essential components of the information system needed to effect decontamination operations?

(3) How should trained personnel and decontamination equipment be prepositioned, organized, and controlled?

(4) How can a decontamination command and control system in a municipality be evaluated?

(5) How can a decontamination command and control system in a municipality be most effectively modeled to provide a ready vehicle for systems analysis?

Each of these questions was examined for various levels of decontamination capabilities, requirements, and attack environments. The various components of a decontamination system in a municipality are identified and embodied in the general command and control system framework. It is shown that a command and control system for decontamination operations must provide both for decisions on whether or not to undertake a mission and for manpower and decontamination resource commitment and allocation decisions. These decision functions require an elaborate information subsystem consisting of organized data files containing prestored (preattack) data and postattack assessments (including system feedback).

The detailed characteristics of the individual components in each of the essential subsystems of a decontamination command and control system are studied. The interrelationships among the individual subsystem components are identified and displayed.

In order to determine the command and control system elements required to accomplish practical decontamination missions in a municipality, the environment (including direct weapons effects) and the system goals are reviewed and analyzed. Basic system evaluation criteria are also discussed and the essential criteria of decontamination command and control system evaluation are identified.

Recommendations and guides leading to the design of a basic command and control system for municipal decontamination are indicated. This aspect of the research is described in detail in Volume II of this report.

E. Real-Cities Analyses

As stated above in Section I, San Jose, California, and Detroit, Michigan were selected for analysis from the five-city study. Twenty-eight sites and facilities were selected for analysis from these two cities. For each of these sites and facilities, the individual gamma radiation contributions from all contributing planes of contamination were computed for specified detector locations using the first computer program described above in Section II-D. These contributions were then used to compute the fraction of dose-rate removed by specified strategies of decontamination around the site or facility. (The second computer program described above in Section II-D was used for this and subsequent computations related to the cost and effectiveness of decontamination). The decontamination strategies are specified by indicating (1) the method of fallout removal (e.g. firehosing), (2) the particular plane or planes decontaminated (e.g., sidewalks and driveways), (3) the fraction of fallout material removed, and (4) the team-hours of effort to be required.

Dose reductions for persons spending specified amounts of time in (perhaps) several detector locations are also computed. The sites and facilities selected for analysis from San Jose and Detroit are listed below:

San Jose, California

1. California Packing Corporation Plant No. 51
2. California Pharmaceutical Laboratory
3. Pacific Telephone and Telegraph Company
4. Dole Corporation Warehouse
5. San Jose Mercury-News Building
6. Western Greyhound Bus Lines Depot
7. San Jose City Lines
8. City Corporation Yard (used for storage of large equipment)
9. Fire Station No. 8
10. Radio Station KXRX
11. Outdoor Areas in a Residential Area
12. Outdoor Areas in the Central Business District
13. San Jose City Hall
14. Valley Fair Shopping Center
15. San Jose Hospital
16. Sewage Treatment Plant

Detroit, Michigan

1. Mercy Hospital
2. E. J. Korvette Department Store
3. Mistersky Power Plant
4. Springwells Pumping Station
5. Cobo Convention Hall
6. City-County Building
7. Detroit City Airport
8. Detroit OCD Building
9. Saint Mary's High School and Elementary School
10. Isaac Crary Elementary School

11. Cadillac Motor Car Division, General Motors Corporation

12. Pure Oil Gasoline Station

The results of these studies, as well as all of the assumptions used, are described in Volumes III and IV of this report.

An analysis of the feasibility of creating decontaminated "islands" or staging areas in municipalities is contained in Volume I. This analysis is based on the data contained in the individual analyses of the sites and facilities listed above. The radiological recovery of an interconnected system of vital elements and their connecting links in a municipality is examined.

III. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The primary conclusion of this study is that the recovery of substantial city areas and multi-building complexes can be accelerated appreciably by practicable decontamination procedures.[1/] (Denial times can be reduced by a factor of ten or more.) Another general conclusion is that, for most indoor detector locations, the roof directly above the detector must be decontaminated if appreciable reduction of intensity is to be accomplished. Similarly, for outdoor detectors, the plane directly beneath the detector must be decontaminated for appreciable intensity reduction. It was also shown that decontaminating all of the vital elements (including the interconnecting links in a city) is feasible when there are no direct weapons effects. Decontaminated "islands"

[1/] These conclusions are based on somewhat idealized conditions. For example, fallout is assumed to be carried far enough away from the detector so as not to contribute at all to the radiation intensity. Other idealizations, particularly those related to weathering of fallout, which may cause protection estimates to be in error, were largely ignored. Also, it should be noted that these conclusions were drawn in the light of uncertainties with regard to the accuracy of the Engineering Manual technique. It is recommended that research be undertaken to determine the extent to which errors are introduced and, if necessary, examine alternative problems, such as Monte Carlo techniques to possibly reduce these errors.

or marshalling areas can be created with reasonable decontamination effort. From a cost and effectiveness point of view, mechanized procedures are by far the best methods for decontaminating paved (outdoor) ground level surfaces. Firehosing (where possible) is the best method for decontaminating a roof. The dose and dose-rate reductions are relatively insensitive to the effectiveness of the decontamination methods as long as at least ninety percent of the fallout material is removed.

Another important conclusion of this study is that a substantial command and control structure is necessary to conduct effective municipal decontamination. Whether or not a separate decontamination command and control system is necessary is not determined in this study--nor will it be determined without a far more extensive research effort which looks at the decontamination system as it relates to other postattack operating systems.

B. Recommendations

On the basis of the above conclusions, it is recommended that decontamination be viewed and analyzed in the context of coordinated municipal recovery from both the residual effects of fallout, as well as direct weapons effects. Particular attention should be given to the control and disposition of the actual fallout material removed from the contributing planes of contamination.

Emphasis should be placed on the development of procedures for computing plane by plane contributions to detectors inside of buildings damaged by blast or fire.

Systems analysis of decontamination should be extended toward the design of an optimal decontamination system for coordinated municipal recovery.

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2. J. T. Ryan, J. D. Douglass, Jr., and H. E. Campbell. Radiological Recovery Concepts, Requirements, and Structures. Final Report: Volume I, General Considerations. Office of Civil Defense Subtask 3233B. Durham, North Carolina: Research Triangle Institute, Operations Research and Economics Division, 16 October 1964.

3. J. T. Ryan, J. D. Douglass, Jr., and H. E. Campbell. Radiological Recovery Concepts, Requirements, and Structures. Final Report: Volume II, Specified Considerations and Supporting Documents. Office of Civil Defense Subtask 3233B. Durham, North Carolina: Research Triangle Institute, Operations Research and Economics Division, 16 October 1964.

4. L. V. Spencer. Structure Shielding Against Fallout Radiation from Nuclear Weapons. NBS Monograph 42. Washington, D. C.: National Bureau of Standards, 1 June 1962.

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13 ABSTRACT

This document summarizes the research accomplished under OCD Subtask 3233B, "Radiological Recovery Requirements, Structures, and Operations Research." The primary objective of this study is to determine cost and effectiveness information relating to the application of decontamination and the extent of its utility when applied to the recovery of extensive city areas in a postattack environment. The general approach toward meeting the objectives of the study, including a brief description of each of the models developed under the contract, is outlined. The command and control aspects of municipal decontamination are summarized, and the results of a systems analysis of decontamination are briefly stated. The results of the extensive real-cities analyses conducted under the subtask are summarized. Both general and specific conclusions and recommendations are stated.

The results of the real-cities analyses showed that roof decontamination is an important part of most combined strategies of decontamination. These results also showed that the recovery of substantial city areas and multi-building complexes could be accelerated appreciably by practicable decontamination procedures.

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